Grantee: Oceana Energy Company
Project Name: Oceana In-Stream Hydrokinetic Device Evaluation
Grant No.: DC 1451

Grant Completion Report

Background:

The project objectives were to demonstrate the performance of the Oceana Energy Company (OEC) hydrokinetic device in Alaskan rivers and its ability to withstand environmental hazards including surface and suspended debris, turbulence and heavy sediment loads and bedload.

The 2nd Generation Oceana device was fabricated and initially tested at the Carderock David Taylor Testing Basin in Maryland. Performance data from the testing basin was used for baseline comparison with subsequent testing in the Tanana River.

Oceana then deployed their device at the Alaska Hydrokinetic Research Center (AHERC) test site in the Tanana River. The project included two seasons (2014 – 2015) of testing at that location.

The last step in the grant-funded testing included an electrical characterization of the hydrokinetic device at the ACEP lab in Fairbanks. This testing was conducted in October 2017 through January 2018.

OEC and project partners also designed a mounting and lowering-raising mechanism that connected the device to the barge and lowered/raised the device into the water for testing in the Tanana River.

Activities:

- Design and build the next generation Oceana device that includes an integral electrical generator, magnetic axial bearings, and hydrofoils specifically designed for river environments.
- In advance of the river testing, characterize the Oceana device at a clean testing center to obtain baseline data. The Carderock tow tank provided for a testing center with precise speed control in flow that is without turbulence.
- Develop, construct and install of the testing infrastructure for river testing operations.
- Deploy and thoroughly test the Oceana device in a realistic, challenging Alaska river environment for two summer series.
- Perform measurements and supporting analyses in the ACEP test lab that characterize the performance of the device in a simulated riverine environment in conjunction with varying load conditions and with supplemental generation sources to simulate operation in a micro-grid installation. Three testing phases were conducted: 1) generator performance in a stand-alone (islanded mode) configuration; 2) generator performance through an inverter when tied to an existing grid (current following in a grid-connected mode); and 3) generator performance through an inverter to an existing grid when that grid has no power (establish and supply voltage in a grid-forming mode).

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Project Costs:

- The amounts of grant funding came from three sources of funds: State of Alaska - $664,710; Denali Commission - $566,235; and Grantee cash match - $620,000. Final reported expenditures are as follows:

Denali Commission:	$ 566,235.00
State of Alaska:	$ 664,710.00
Grantee Cash Match:	$ 654,349.90
Total:	$1,885,294.90

Project Outcomes:

- Being the first customer at any new facility usually results in many unexpected problems and challenges. Even though that was anticipated, there were no significant issues. Oceana benefited from the test site and facilities that AHERC established on the Tanana River near Nenana. The barge and associated equipment performed as intended and accelerated the ability to perform the hydrokinetic device evaluation.
- The Tanana River is a stressing environment. The nature of the river with debris, sediments and changing flow make for a challenging demonstration of hydrokinetic technology. If a device can survive the Tanana it can probably survive anywhere.
- Given the amount of debris that floats down the Tanana daily, it had been expected that the device would experience some type of significant impact during operation. AHERC had done a tremendous job on developing a debris diverting system and locating the test site in the river to minimize potential interactions. While several impacts on the debris diverter were observed, no significant impacts were experienced by the barge or device. While the threat still exists, this approach provides a means to minimize potential problems.
- On the last afternoon of river testing, the device did experience an impact by a submerged log. It was something that the debris diverter was not designed to handle but something that had been concerned about before the tests. Oceana was excited to see that the even though the log had jammed in to the center of the device, that the device continued to operate and did not experience any damage other than some scratches.
- The magnitudes of the turbulence was a bit more than expected. This was evident in both the water speed measures (inputs) as well as all the response signals. The Oceana device was able to function within this turbulent environment without any negative consequences.
- In 2014 the field testing on the Tanana River occurred late in the season and the flows were low. But in 2015 with the testing planned to occur near the peak flow conditions, the current speeds were high, thus producing higher power levels. In retrospect, it was useful to record data spanning a larger range of water speeds.

- During the three testing cycles, a vast amount of data was generated. Most of the data was of high quality that was able to shed significant insight into the testing environment and the performance of the device. The final report includes three appendices with descriptions of the data gathered and the methods of interpretation of this data.
- The use of the selectable load-bank turned out to be a very useful method to determine the optimum resistive load to extract the maximum power. As is evident in all three test series, the optimum was a setting of approximately 20 amps which corresponded to resistance of 25.6 ohms. While the power can vary 10% across the various settings, the reported power coefficients assume operation at this optimum point.
- An evaluation of the power output from the device is generally of most interest. With the water speed fluctuating over any sampling period, an instantaneous or even a period averaged power number is not as meaningful as the coefficient of performance (Cp). This coefficient is a dimensionless measure of the power output, that normalizes out the effects of device size and water speed. Based on the DC power at the load-bank, which includes all possible losses (lowest power), the derived Cp for both the 2014 and 2015 field testing was 0.26.
- The following outcomes were achieved during the lab characterization testing of the Oceana hydrokinetic device: 1) during the testing in the islanded mode, the generator was able to produce nearly 10 kW; 2) the efficiency of the generator in the grid-connected mode ranges from 84% at 25 rpm to 97% at 80 rpm; and 3) the efficiency of the generator in grid forming mode was between 91.8% at 60 rpm to 96.7% at 70 rpm. The overall system efficiency the grid forming mode ranged from 75% to 87%.

Problems Encountered:

- Three failures occurred with the data acquisition equipment, all with different root causes. The first failure occurred during the initial test at Carderock tow tank when the data logger experienced a significant short circuit causing several internal circuit boards to fail and electrical connections to melt. The unit was able to be partially restored later in the week after replacement of some of the circuit boards available from the manufacturer so that the testing cycle could be completed using that device and by manual recording of various electrical output voltages. The second failure occurred in July of 2015 when water got into the capacitor box, which then blew out the data logger due to an overvoltage condition. The water came from a rainstorm and was able to enter the protective box due to failed conduit to box seals. Repairs were instituted to refurbish the data logger unit and to add some resistors to a junction box. The third failure occurred in late July 2015 after the onboard generator shut down due to lack of fuel, which reduced the load on the load bank and over-voltage condition occurred one more time at the data logger, frying it completely. Because the data collection season was nearly complete, it was decided to continue running the field test for one additional week without the data logger in place.

- Several problems occurred in the course of the lab characterization testing. All were related to the Ideal Power inverter unit that converts the DC power output from the turbine generator to AC power compatible with the grid. The inverter system failed multiple times during testing. Some problems were software in origin, related to the programming of the unit, while others were from failure of electrical components within the inverter due to overload of some of the inverter circuits.
- There was also interest in testing whether the battery backup would allow support of grid loads in excess of what the generator was putting out (due to low rpm). These tests usually met with system failure before such tests could be implemented or completed. In the end Oceana recognized an alternate inverter will be needed to successfully integrate its device in a local power grid application.

Conclusions and Recommendations:

- The Oceana hydrokinetic device operated without failure through both seasons of field testing. While this was always the design intent and hope, it was a validation that the device can operate in harsh environments and the basic technology is sound.
- The inclusion of the Carderock testing was a critical element in determining performance. It provided a set of data under clean conditions that help to better understand the performance in the river.
- As with any development effort, once an article is built and assembled, there are typically ideas for improvements. While the overall concept performed as expected, there are several details that could be modified to improve the ease of assembly of the device and the test hardware. It is the intent that these improvements will be included in the next generation of the Oceana device and the testing setup.
- Regarding the three failures with the data acquisition equipment, all failures could have been avoided with improved isolation of high voltage signals. Future testing will consider improved isolation methods such as optical isolation methods.
- Because of some prior failures on river deployments due to debris issues, many developers have avoided rivers that might cause a similar failure. This has caused many to believe that debris laden rivers may not be applicable to hydrokinetic energy. This is unfortunate because the greatest need for energy is near rivers that normally contain debris. By taking the debris challenge head on, this project can demonstrate to others that it is possible plus also provide a potential path to overcome this great challenge.

- The various instrumentation and instrumentation deployment methods that were used both for the device and for the river characterization provide some valuable lessons and examples that other may utilize.
- A particularly interesting finding was the series of tests performed with the device at different depths. These are documented in the final report. The device was designed to deploy at just over 6 foot depth to centerline, which was the where most all other data was recorded. But a special series looked at the performance as the device was raised in one foot increments. The interesting and useful result of this exercise was that the device continued to output full power even when raised 3 feet, which at that point the tips of the fins are at the water surface. This has significant implications for future testing and deployments.
- Overall, the majority of the objectives of the electrical evaluation testing were achieved and the performance of the generator was excellent. But throughout the entire electrical characterization the inverter that was supplied by Ideal Power was a problem. It was the source of numerous delays and failures. It is Oceana's final recommendation to never use an Ideal inverter nor any other product from Ideal again in any project.